CONVERTER

The present invention relates to a converter.

In the case of converters, is known that the actual value I_actual of the motor current can be measured, the current-
5   sensing means being situated in the converter. The signals provided by the current-sensing means of the control electronics are initially supplied to a filter 1, e.g. a PT1 filter, as shown in Figure 1. Therefore, microcontroller 2 is provided with filtered measuring signals, and interference
10   signals become suppressible. The PT1 filter advantageously takes the form of a low-pass filter having a time constant of, e.g. 20 μs.

In the case of these converters, it is disadvantageous that
15   when long cables are used between the converter and the powered electric motor, the capacitance of the cable produces recharging-current peaks that are too high. This is because the converters are operated in a pulse-width-modulated manner, and a change in voltage at the output of the converter
20   produces large, short-term, charging-current peaks of this cable capacitance.

Therefore, the object of the present invention is to improve the current sensing in converters.
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The object of the present invention is achieved by the converter having the features indicated in Claim 1.

In the case of the converter, the essential features of the
30   present invention are that it at least includes means for measuring the currents supplied to the electric motor that is powered by the converter, the means for current sensing being

situated inside the converter, and the signals of the means being fed to a nonlinear filter, whose output signals are fed to an additional filter that is connected to an analog-to-digital converter.

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In this context, it is advantageous that a high control performance and control quality are attainable in converters, which are connected, in each instance, to the powered electric motor via long cable, for the recharging-current peaks

10   produced due to the high cable capacitance may be effectively filtered away, in particular at least one order of magnitude more than in the case of a mere PT1 filter. In this context, it is important that not only the peak value of the filtered signal is less, but that above all, the voltage-time area may

15   be provided to be much less than in the case of a PT1 filter or other linear filters as well.

The nonlinear filter is always designed in such a manner, that the changes in the value of the current, which are motor-

20   dependent, i.e. determined by the design of the electric motor, are transmitted essentially undisturbed. In contrast to this, recharging-current peaks of shorter duration than the characteristic time of the nonlinear filter are suppressed in the measuring signal. However, changes in current that are

25   caused, for example, by mechanical load changes of the rotor of the electric motor are transmitted essentially unchanged.

In one advantageous refinement, the analog-to-digital converter is integrated in a microcontroller or

30   microprocessor. In this context, it is advantageous that as few inexpensive components as possible are usable.

In one advantageous refinement, the nonlinear filter is a run-up transmitter. In this context, it is advantageous that a

component is producible, which is especially simple to construct.

In one advantageous refinement, the run-up transmitter

5 includes a comparator and an integrator. This offers the advantage that standard components may be utilized.

In one advantageous refinement, the additional filter is a PT1 filter. This offers the advantage that the circuitry of the

10 related art only requires a few simple modifications.

In one advantageous refinement, the value corresponding to the rated current of the converter is attainable for the run-up transmitter in a time between 5 and 10 µs. This provides the

15 advantage that the filtering is highly effective and the voltage-time area is much less than in the case of using a PT1 filter having a corresponding time constant.

In one advantageous refinement, the PT1 filter has a time

20 constant having a value between 15 and 25 µs, in particular, approximately 20 µs. This provides the advantage that components of the related art are usable.

Further advantages are yielded from the dependent claims.

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List of reference numerals

1 filter

2 microcontroller

5   3 run-up transmitter

31 comparator

32 integrator having a level converter

41 operational amplifier

42 operational amplifier

10   R1 resistor

R2 resistor

C1 capacitor

C2 capacitor

The present invention will now be explained in detail with reference to figures:

A principal feature of the present invention is sketched in
5   Figure 2. A run-up transmitter 3 is connected in outgoing
circuit to the current-sensing means. The output signal of
the run-up transmitter is subjected to the usual filtering,
i.e. fed to low-pass filter 1, and the signals filtered in
this manner are then fed to the microcontroller.
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In the ideal case, the run-up transmitter has the
characteristic that its output signal increases at a fixed
rate of change, as long as the output voltage is less than the
input voltage. In the same way, its output signal decreases
15   at a fixed rate of change, as long as the output voltage is
greater than the input voltage. Therefore, when the input
signal changes more slowly than what corresponds to these two
rates of change, then the output signal is equal to the input
signal. Deviations from this ideal behavior occur in
20   practice.

A basic design of the run-up transmitter is shown in Figure 3.
In this context, the output of a comparator 31 is fed to an
integrator 32, and the output signal of integrator 32 is used
25   by comparator 31. Therefore, as long as there is a difference
between the input and output variables of the run-up
transmitter according to Figure 3, the output of comparator 31
will have a positive or negative value as a function of the
algebraic sign of the difference. The output signal of
30   integrator 32 increases linearly with time or decreases
linearly with time. All in all, a short-term, rectangular
input variable is converted into a small triangular pulse.
The slope of the triangular waveform is a function of the time
constant of the integrator. In the present invention, this is
35   selected to be greater than the typical duration of the

recharging-current peak for the charging of the cable
capacitances.

The maximum slope of the output signal of the run-up
transmitter is selected so that its magnitude is always
greater than the maximum slopes of the motor-current
characteristic. These slopes of the motor-current
characteristic are essentially determined by the inductance of
the electric motor and the applied voltage and the induced
voltage in the motor. Therefore, the motor currents are not
low-pass filtered, but the current characteristic to be
measured is passed through the subsequent circuit elements
essentially unchanged. However, the recharging-current peaks
are sharply reduced, because they have a considerably greater
slope than the mentioned, maximum voltage of the output signal
of the run-up transmitter.

A concrete example of a circuit layout is shown in Figure 4.
However, other circuit layouts may also be advantageously used
for implementing the present invention. In Figure 4, the
comparator is implemented with the aid of operational
amplifier 41, as well as the surrounding circuit elements.
Its output signals are fed to integrator 42, R4, R5, R6, R7,
and C1 with level conversion, this integrator having a time
constant between 2 and 10 µs, and operational amplifier 42
being provided to be used for level conversion. The output
signal is fed back to the input of the comparator via resistor
R8. Capacitor C2 is used to prevent the set-up from
oscillating. Further components are also provided and
dimensioned for preventing oscillation, such as C3. The
comparator is implemented as an amplifier having a high gain,
which is determined by R1, R9, R2, and R8.

Shown in Figure 5 is an example of a pulse, which symbolically
sketches the time characteristic of a recharging-current peak

normalized to 1, the recharging-current peak having a pulse width of somewhat greater than 1 µs. In the case of shielded cables several meters long, for example 20 m, real recharging-current peaks exhibit peak values of several ampere, for

5   example 10 ampere and greater. The real time characteristics are not rectangular pulses as shown in Figure 5, but have a sharply damped oscillatory characteristic, which is also determined by the inductance of the cable and by other variables. However, the symbolic shape of the recharging-

10   current peak is used for more effectively understanding the present invention and the behavior of the run-up transmitter in comparison with the related art. The voltage-time area of the represented, symbolic recharging-current peak is comparable to real recharging-current peaks.

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Figure 6 shows the measured response of a conventional PT1 filter having a time constant of 20 µs, to the recharging-current peak of Figure 5. This corresponds to the related art. The filtered value reaches a magnitude of 0.08, i.e. 8%

20   of the real recharging-current peak. The discharging time of the PT1 filter is very long. The voltage-time area is very large as well.

Figure 7 shows the measured response of the run-up transmitter

25   to the recharging-current peak of Figure 5. The peak value reaches a magnitude of 0.05, i.e. only 5% of the real recharging-current peak. The discharging time of the run-up transmitter is very short and is approximately 2 µs. The voltage-time area is very small as well. Deviations from the

30   ideal triangular shape of the response result from the fact that the comparator does not have an infinitely high amplification, but only a finite amplification for suppressing oscillatory behavior.

Operational amplifier 41 is advantageously selected to from saturation into the active control range within less than 200 ns.

5   Figure 8 shows the measured response, when conventional filter 1 is connected in outgoing circuit to run-up transmitter 3. It is clearly evident that the recharging-current peak has only a very small effect on the output signal fed to microcontroller 2.

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Therefore, the present invention provides a nonlinear filter, which suppresses recharging-current peaks in a highly effective manner and, consequently, also allows a very high control quality in the case of converters having long cables

15   leading to the powered motor.